Capability in Theory, Modeling, and Validation for a Range of Innovative Fusion Concepts using High-Fidelity Moment-Kinetic Models

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U.S. DEPARTMENT OF ENERGY

Team members and roles

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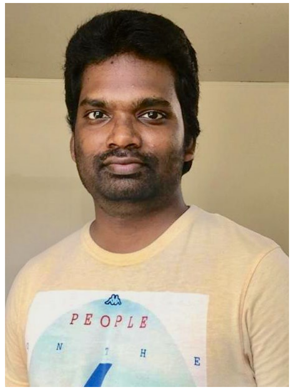

Suresh Murugaiyan

Daniel Weber

Kevin Brannick

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Postdocs (present and forthcoming): Petr Cagas, Mana Francisquez, Chirag Rathod

PhD students: Kolter Bradshaw, Suresh Murugaiyan, Daniel Weber

MS and BS students: Kevin Brannick, Liam Welch

High-level motivation and goals of the project

- ***Advanced computing*** to better understand and advance the performance of lower-cost fusion concepts
- Versatile set of computational plasma modeling capabilities for ***kinetic and reduced models*** to study ***plasma equilibrium, stability, plasma-wall interactions*** using the Gkeyll code
- Application of a ***liquid metal multi-phase modeling capability*** to study liquid wall dynamics along with ***validation experiments***

- Computational simulation partnership with the following concept teams:
  - Plasma-jet magneto-inertial fusion (Los Alamos National Laboratory)
  - Wisconsin High-Field Axisymmetric Magnetic Mirror (UW-Madison) and Centrifugal Mirror Fusion (UMBC)
  - General Fusion's Magnetized Target Fusion

Major tasks (and technical risks), milestones, and desired project outcomes

- Major tasks/milestones:
  - **Mirrors**: Provide guidance on moment and kinetic equilibria and stability (UW-Madison and UMBC)
  - **PJMIF**: Provide guidance on optimization of jet parameters for liner uniformity (LANL)
  - **Plasma-surface interactions**
    - **Plasma-solid wall interactions**: Verified and validated sheath studies with electron and ion emission, impact on wall, impact on plasma
    - **Liquid-wall dynamics**: Verified and validated multi-phase liquid metal modeling capability (General Fusion data) and liquid free-surface experiments (Virginia Tech)

- Key technical risks
  - Reduced moment models may not produce results to desired fidelity (Mitigation: use kinetic models with larger computational cost)
- Desired project outcomes
  - Verified and validated, moment, kinetic, and incompressible multiphase predictive capability
  - Provide understanding of critical physics necessary for fusion concept viability
  - Iterate with concept teams to understand parameter space of each concept

Key techno-economic metrics of the project

- Access to ***high-fidelity computation*** is critical to accelerate the development of lower-cost fusion concepts
- ***Public and private entities*** will benefit from the scientific contributions of this team while also benefiting through ***access and use*** of these computational capabilities
- Our open-source codes are regression-tested to produce ***fully reproducible*** results
- Provides an ***easy to use*** framework for fusion concept teams
- Our ***open-source***, high-fidelity capabilities are accessible by the broader fusion community